AQIRP AND EPEFE - A COMPARISON OF THE PROGRAMS AND THEIR RESULTS

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ABSTRACT

Since it was established in 1989 by 14 oil companies and three domestic automakers, the U.S. Auto/Oil Air Quality Improvement Research Program (AQIRP) has made substantial progress in developing an information base of fuel and vehicle effects on emissions. This program was the largest and most comprehensive project of this nature ever attempted. More recently, the European Programme on Emissions, Fuels, and Engine Technologies (EPEFE) marked an unprecedented cooperation between the European motor and oil industries to extend the information on fuels and engine technologies for the European continent. AQIRP and EPEFE were the first large scale systematic efforts to develop extensive data on the inter-relationships among fuel composition, vehicles, emissions, and air quality. This scientifically based information will allow legislators and regulators to design cost effective methods with which to achieve their clean air goals.

INTRODUCTION

Motor vehicles have historically been viewed as one of the main sources of ozone and carbon monoxide pollution in the United States. But over the past three decades, the contribution of the automobile to urban pollution has been steadily decreasing. Nationwide, emissions of HC, CO, and NO_x from on-road vehicles have declined in absolute quantity, as well as relative to other sources of air pollution.

Even though today's new vehicles produce substantially less ozone-forming HC and NO_x emissions than the new vehicles of 25 years ago, ozone concentrations in 33 urban areas remain above the current federal air quality standard. In the same time frame, nine cities were above the carbon monoxide standard. While these numbers represent a major improvement from prior years, significant future reductions in emissions from a variety of sources – stationary and mobile – will be required to help meet the ozone standard in the remaining areas.

Similarly, many European cities are experiencing unique and significant problems caused by the use of diesel fuel by both passenger cars and trucks and the consequent increased burden of particulate matter. Reductions from many sources, including mobile, will be needed to tackle the air quality problems.

Mobile source reductions will be achieved in many ways. Future vehicle systems are being designed to achieve lower emissions. In addition, gasoline and diesel fuels are being reformulated in some areas to reduce emissions from both existing and future vehicles. Alternative fuels also may play a role in decreasing emissions.

In the past, the successful achievement of these goals has been hampered by a lack of scientific knowledge in a variety of areas. For instance, one specific need has been comprehensive data about the interrelationships among fuel composition, vehicles, emissions, and air quality. The U.S. Auto/Oil Air Quality Improvement Research Program (AQIRP) and the European Programme on Emissions, Fuels, and Engine Technologies (EPEFE) were created to develop that knowledge.

AQIRP

The Auto/Oil Air Quality Improvement Research Program (AQIRP) was established in 1989 by 14 oil companies and three domestic automakers. The program has made great progress in developing an information base on fuel and vehicle effects on emissions. The overall objective of AQIRP has been to provide this data to help legislators and regulators achieve the nation's clean air goals through a research program that included:

(1) Estimation of potential reductions in vehicle emissions from changes in fuel composition.
(2) Estimation of potential improvements in air quality - primarily ozone - and fuel reformulation.
(3) Estimation of the relative cost effectiveness of some fuel/vehicle systems.

This program was the largest and most comprehensive project of this nature ever attempted.

Over the course of the six-year program, AQIRP conducted more than 5,000 emissions tests using over 80 fuel compositions in over 100 vehicles. The tests measured engine, tailpipe, evaporative, and running-loss emissions, and quantified the concentrations of 153 different organic compounds plus oxides of nitrogen (NO_x) and carbon monoxide (CO). Using the 175 megabytes of data generated by these tests, AQIRP has developed an extensive data base of fuel composition and vehicle effects on emissions.

The emissions data were employed in air-quality modeling studies for New York City, Los Angeles, and either Chicago or Dallas-Fort Worth, using state-of-the-science models and emissions inventories. In these studies, AQIRP focused on fuel and vehicle changes that would reduce predicted ozone air pollution. Extensive refinery modeling studies were also conducted to develop cost estimates for producing various research gasoline formulations.

AQIRP found that the following changes can be effective in reducing vehicle mass emissions and/or improving ozone air quality.

- Lowering the aromatic content of gasoline lowers toxic emissions.
- Lowering the T_{90} and/or T_{50} (boiling range) of gasoline reduces ozone and exhaust HC emissions.
- Lowering the sulfur content of gasoline decreases exhaust emissions of HC, CO, NO_x, toxics, and ozone.
- Lowering the olefin content of gasoline reduces NO_x and ozone, but increases exhaust HC emissions.
- Adding oxygenates to gasoline reduces CO in older and current technology vehicles.
- Lowering the Reid vapor pressure (RVP) of gasoline reduces evaporative emissions, exhaust HC and CO emissions, and ozone.
- Identifying and repairing high-emitting vehicles reduces evaporative emissions, exhaust emissions and ozone.
- The introduction of newer vehicle technology has resulted in decreases in regulated emissions, toxics and ozone.

EPEFE

The European Programme on Emissions, Fuels, and Engine Technologies (EPEFE) began in 1994. It was an essential part of the European Auto-Oil Programme which constituted a new approach in setting environmental legislation and which harnessed the expertise of the European Commission, industry, and consultants in Europe. The intent of the Auto-Oil Programme was to identify which new measures may be required to meet rational air quality objectives in the most cost effective way, derived from scientifically sound data. The EPEFE program was designed to extend the information on the relationships between fuel properties and engine technologies and to quantify the reduction in in-use emissions that can be achieved by combining advanced fuels with the vehicle/engine technologies under development for the year 2000. Specifically, EPEFE included:

(1) Assessment of the current state of emissions relationships available from fuels/vehicles.
(2) Generation of new data for the air quality modeling program in Europe.
(3) Estimation of the cost benefit of fuel/vehicle technologies relative to the year 2000 requirements.

During its two years of activity, EPEFE examined 12 gasolines in 16 gasoline-powered vehicles, and 11 diesel fuels in 19 light duty vehicles and 5 heavy-duty engines. More than 2000 emissions tests were performed, providing over 500,000 measurements of HC, CO, and NOx exhaust emissions, and diesel-generated particulates.

The emissions data from EPEFE were used in air quality modeling studies for seven European cities including London, Cologne, Hague, Lyon, Athens, Milan, and Madrid. Additional studies are also being conducted to identify the most cost effective way to implement the findings.

The following EPEFE results confirm that both fuels and engine technologies are important determinants of motor vehicle emission levels.

* Lowering the aromatic content of gasoline decreases exhaust HC and CO.

* Reducing the aromatic level of gasoline reduces CO_2 at each E100 volatility level with no impact on fuel consumption.

* Increasing the mid-range volatility of gasoline decreases exhaust HC.

* Decreasing the T90 (boiling range) of gasoline reduces light-duty PM and heavy-duty exhaust NO_x.

* Lowering the sulfur level of gasoline reduces exhaust HC, CO, and NO_x.

* Decreasing the density of diesel fuel reduces light-duty diesel HC, CO, and PM, and reduces heavy-duty diesel NO_x.

* Decreasing the polyaromatic content of diesel fuel reduces light-duty diesel NO_x and PM, heavy-duty diesel HC, NO_x and PM.

* Increasing the cetane rating of diesel fuel reduces diesel HC and CO.

Conclusions About AQIRP and EPEFE

These landmark cooperative research programs have contributed enormously to the understanding of the relationships between fuels and vehicles.

AQIRP was a milestone in cooperatively developing a sound technical database for use by regulators. In addition to developing new test techniques for measuring and speciating emissions, the program also made significant contributions to the development of atmospheric models and the understanding of how fuels impact atmospheric pollution.

The California Air Resources Board (CARB) has adopted gasoline specifications based on program findings. CARB and the U.S. Environmental Protection Agency have both made use of AQIRP's data in developing mathematical models to predict emission changes from changes in fuel properties. AQIRP data will continue to influence decisions on air quality improvement control options for years to come.

EPEFE, which was inspired by the AQIRP, is providing similar benefits for Europe as it provides a scientific basis for the establishment of cost effective European exhaust emission standards for the year 2000. The program brought together European Union Commission, the European oil industry, and the European auto industry for the first time in a large scale cooperative research program. The program enhanced the body of data already in existence within Europe and from AQIRP to expand on the relationships between fuels and automotive emissions. The EPEFE process aided the search for a balanced set of measures which could help meet the European Union's air quality objectives.

These programs have shown that:

* Oil and automotive industries can work together effectively on important research objectives.

* Both programs have made important findings and have substantially increased the body of knowledge of vehicle/fuel effects.

* Matching fuels to vehicles is critical. They form a "system" which maximizes the potential of each.

* Controlling mobile source air pollution requires a detailed understanding of fuel/vehicle systems, inventories, atmospheric chemistry, and cost effectiveness.

Results (Gasoline)

AQIRP

- Aromatics (per vol. % decrease) FTP Cycle

HC	CO	NOx
-0.2	-0.5	NS

Note: AQIRP results are for "Current" Technology vehicles unless otherwise noted.

EPEFE

- Aromatics (per vol. % decrease)* MVEG 11-second Cycle
  - * @ E100 = 35%

HC	CO	NOx
-1.1	-0.6	+0.5

  - * @ E100 = 50%

HC	CO	NOx
-0.4	-0.6	+0.3

  - * @ E100 = 65%

HC	CO	NOx
-0.3	-0.6	+0.1

* 5% CO_2 reduction from high to low aromatics

Results (Gasoline cont.)

AQIRP

- T_{90} (per 5°F decrease)

HC	CO	NOx
-1.4	NS	+0.3

- T_{50} (per 5°F decrease)*

HC	CO	NOx
-2.1	NS	+1.3

* HC results for 180 - 240°F range
CO and NOx results for 185 - 215°F range

EPEFE

- T_{90} - held constant in EPEFE matrix for each level of E100
- E-100 (per % evaporated)
  - * E-100 @ 20% Aromatics

HC	CO	NOx
-0.8	-0.1	+0.2

  - * E100 @ 35% Aromatics

HC	CO	NOx
-1.2	-0.1	+0.4

  - * E100 @ 50% Aromatics

HC	CO	NOx
-1.4	-0.1	+0.7

Results (Gasoline cont.)

AQIRP

- Sulfur (per 50 ppm decrease - not linear) FTP Cycle

HC	CO	NOx
-2.2 to -2.9	-2.4 to -2.8	-1 to -1.5

EPEFE

- Sulfur (per 50 ppm decrease)
  - * MVEG Cycle - composite new 11 sec. idle

HC	CO	NOx
-1.2	-1.2	-1.4

  - * EUDC Portion (Sulfur results)

HC	CO	NOx
-7.1	-5.8	-2.8

  - * ECE Portion (Sulfur results)

HC	CO	NOx
NS	-0.9	NS

Results (Gasoline cont.)

AQIRP

- Olefins (per vol. % decrease)

HC	CO	NOx
+0.4	NS	-0.4

- Oxygenate (per wt. % increase)

HC	CO	NOx
-1.9	-4.1	NS

- RVP (per psi decrease)

HC	CO	NOx
-4%	-9%	NS

EPEFE

Results (Diesel)

AQIRP

- Diesel - not tested

EPEFE

- Reducing Density 0.855 - 0.828 g/l

HC	CO	NOx	PM
		LD	
-18.9	-17.7	+1.4	-19.4
		HD	
+14.3	+5	-3.6	NS

- Reducing Polyaromatics 8 to 1% m/m

HC	CO	NOx	PM
		LD	
+5.5	+4	-3.4	-5.2
		HD	
-4	NS	-1.7	-3.6

Results (Diesel cont.)

AQIRP

- Diesel - not tested

EPEFE

- Increasing Cetane number 50 to 58

HC	CO	NOx	PM
		LD	
-26.3	-25.3	NS	+5.2
		HD	
-6.3	-10.3	-0.6	NS

- Reducing T_{95} from 295 - 370°C

HC	CO	NOx	PM
		LD	
NS	-1.8	+4.6	-6.5
		HD	
+13.4	+6.6	-1.7	NS